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ABSTRACT

This study examined the mathematics achievement of grade three English-speaking pupils enrolled in French immersion or in an English program as a function of language of instruction and the extent to which their teachers used a locally developed mathematics curriculum document. The sample consisted of eight English program classes and four French immersion classes. French and English versions of an objectives-based mathematics test were administered in October, 1981, and equivalent forms plus a nonverbal aptitude test were given to the same pupils in May, 1982. All participating teachers completed a teacher survey. The English program pupils made significantly greater mathematics gains than their French immersion peers, although the latter had higher initial average scores. Regardless of program, pupils whose teachers reported greater use of the new curriculum document made more mathematics progress than did pupils whose teachers reported less use of the document. The combined effects of program and teacher variables affected mathematics achievement of the grade three pupils as predicted. (Author)

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# Mathematics Achievement: Interactive Effects of Language of Instruction and Teacher Use of New Curriculum Materials

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## Abstract

This study examined the mathematics achievement of grade three English-speaking pupils enrolled in French immersion or in an English program as a function of language of instruction and the extent to which their teachers used a locally developed mathematics curriculum document. The sample consisted of 8 English program classes and 4 French immersion classes. French and English versions of an objectives-based mathematics test were administered in October, 1981, and equivalent forms plus a nonverbal aptitude test were given to the same pupils in May, 1982. All participating teachers completed a teacher survey. The English program pupils made significantly greater mathematics gains than their French immersion peers, although the latter had higher initial average scores. Regardless of program, pupils whose teachers reported greater use of the new curriculum document made more mathematics progress than did pupils whose teachers reported less use of the document. The combined effects of program and teacher variables affected mathematics achievement of the grade three pupils as predicted.

Mathematics Achievement: Interactive Effects of Language of Instruction and Teacher Use of New Curriculum Materials

The purpose of the present study was to investigate the interactive effects between language of instruction and teacher use of new mathematics curriculum materials recently developed by the Carleton Board of Education, upon the mathematics achievement of grade three English-speaking pupils enrolled in English and French immersion programs respectively. The major factors leading to the development of a new mathematics curriculum in this school board were the publication of a new mathematics curriculum guide by the Ontario Ministry of Education in 1980 and a needs assessment conducted by the school board in 1979 which revealed the need for an up-dated and more uniform curriculum. The new mathematics curriculum has been distributed to all teachers as a detailed document which, at the grade three level, considers four basic strands: arithmetic, geometry, graphing, and measurement. Each lesson within a strand is structured in terms of four components: objectives, teaching activities/strategies, sample evaluation, and references.

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The work reported herein presents some aspects of a longitudinal evaluation study of a new mathematics program, sponsored by the Carleton Board of Education. The authors gratefully acknowledge the excellent support and cooperation of school board personnel, and wish to note explicitly those of Mr. Russ McGillivray, Dr. David Ireland, Mr. Bob Lafleur, and Mr. Dave Thorsell, during the conduct of this project.

French Immersion and Mathematics Achievement

During the 1970's, in the wake of the St. Lambert Study (Lambert & Tucker, 1972), the "immersion" approach has arisen as an increasingly accepted educational innovation for second language learning. This approach is intended for English-speaking pupils and involves the use of French as the language of instruction for most or all school subjects.

The aim of any primary school immersion program is to develop a high degree of proficiency in second language (usually French in Canada) skills while maintaining a level of proficiency in first language (English) skills and in specific subject matter achievement which is consistent with that found in unilingual English programs.

The effects of French immersion upon the achievement of the pupils involved have been widely studied for more than a decade. The key findings have been that pupils enrolled in immersion acquire substantial second language (French) skills without detriment to their first language skills or to scholastic achievement (Bruck, Lambert, & Tucker, 1974; Edwards, Fu, McCarrey, & Doutriaux, 1981; Lambert & Tucker, 1972; Swain, 1974, 1978; Cummins, Note 1). However, such findings have been far more thoroughly documented in the realm of language skills than in the area of specific school subject matter achievement. In mathematics, for example, findings have been limited to those obtained from standardized tests, most frequently the mathematics subtest of the Canadian Tests of Basic Skills or of the Metropolitan Achievement Test (e.g., Barik & Swain, 1975; Barik, Swain, & Nwanunobi, 1977; Edwards, et al., 1981;

Lambert, 1978; Genesee, Note 2; Scott, Note 3). Such tests can only attempt to measure the core content which is common to most mathematics curricula across North America.

The present study is based on the idea that mathematics skills of pupils are best measured through tests constructed particularly for the curriculum recommended by their own school system, and that the several key strands of the mathematics curriculum are best measured by separate subtests. The grade three curriculum of the Carleton Board of Education subdivides mathematics into four strands: arithmetic, geometry, graphing, and measurement. By using curriculum objectives-based achievement tests with subtests in these strands (see Fu & Edwards, Note 4), the authors hope to provide more valid data than have been available to date for contrasting the mathematics skills of French immersion and English program pupils.

Teacher Attitudes Toward Mathematics

There is a substantial body of literature indicating that teacher attributes significantly influence the scholastic achievement of their pupils (e.g., Brophy & Evertson, 1976; Evertson, Anderson, Anderson, & Brophy, 1980; Good & Grouws, 1977). However, studies of immersion programs have generally ignored teacher variables (Swain, 1976).

The present study proposes that the extent to which teachers make use of new curriculum materials provides an indirect measure of their attitudes toward the program in question. It is therefore believed that

teacher attitude, assessed as self-reported amount of use of the new mathematics curriculum document prepared by the school board, may influence the mathematics achievement of the pupils.

Formulation of the New Mathematics Curriculum

Traditionally, French immersion teachers have adhered to carefully sequenced and structured curricula, acknowledging that the pupils' second language level was less than optimal. English teachers, by contrast, have not usually been thus constrained in their unilingual program teaching.

It may be that, during the early grades, a second language handicap of French immersion pupils has been offset by their teachers' adherence to a rigorously structured and sequenced curriculum, and in consequence their subject matter performance has been comparable to that of unilingual English program peers, usually as measured by standardized tests.

In this study, a new mathematics curriculum document, which provides a rigorous and detailed articulation of the grade three program, was developed and distributed to all teachers in both French immersion and English programs. If the teachers used this document extensively, they would no doubt provide a fully comparable program to both French immersion and English program pupils. One would therefore expect, in this context, that language competence differences between the two groups of pupils would lead to differences in measured mathematics performance, in favor of English program pupils. But, this would only be true if the teachers used the document extensively. If they did not, either the traditional

contrast would be applicable and there would be no performance difference in the two groups of pupils, or in fact the French immersion pupils might perform better, to the extent that they receive extra help from interested parents and teachers.

For the above reasons, an interactive effect between the program and teacher variables upon the mathematics achievement of grade three pupils is hypothesized. More specifically, the following hypotheses are formulated:

1. When French immersion and English program teachers make extensive use of the school board's newly developed mathematics curriculum document in comparable French and English versions, the consequent mathematics achievement of the English program pupils will be superior to that of the French immersion pupils.

2. When French immersion and English program teachers do not make extensive use of a comparable mathematics curriculum, the consequent mathematics achievement of the French immersion pupils will be superior to that of the English program pupils.

## Method

### Sample

The population of this study consists of all grade three pupils in a large urban Ontario school board. Classes rather than individual pupils were the sampling units because the focus of this study is on the new mathematics program as it is taught in regular classes. Class size generally

ranged from 25 to 35 pupils. Split-grade classes were excluded from the population before sampling.

In the school year 1981-82, two random samples were drawn from the total population. The first sample consisted of 223 pupils enrolled in 8 grade three regular English program classes, randomly selected from 38 nonsplit classes, and their 8 teachers.

The second sample consisted of 92 pupils enrolled in 4 grade three early French immersion classes, randomly selected from such 14 nonsplit classes, and their 4 teachers. All of the French immersion curriculum, except for a daily period of English Language Arts, was taught in French by French-speaking teachers.

Instruments

The instruments used in this study consisted of two tests and one survey form. Each of the instruments is described below.

Criterion-referenced mathematics achievement test. This test was constructed by the authors in close collaboration with school board personnel, assigned specifically for this purpose. It is important to stress that this test is intended to reflect the specific objectives and content of the school board's new mathematics curriculum document.

In the final version, there are two equivalent test forms, A and B, in each language, English or French. Each form consists of 50 multiple choice items and yields four subscores in the strands of arithmetic (19 items), geometry (10 items), graphing (2 items), and measurement (19 items),

as well as a total score. The number of test items per strand is in direct proportion to the number of objectives per strand in the school board's new mathematics curriculum document.

This test was carefully validated by means of qualitative and quantitative analyses, with consequent revisions of items (for details, see Fu & Edwards, Note 4).

Cattell's Culture Fair Intelligence Test. As a measure of general aptitude, Form A, Scale 2 of the test was selected. The authors found it necessary to administer this nonverbal group test in order to control statistically for possible differences in the general abilities of the groups to be contrasted. If, for example, there were a difference in the average general ability of English program and French immersion pupils, it would be important to control for it statistically when contrasting the mathematics scores of the two groups. The test is well suited for this study, having adequate evidence of reliability and validity for a wide age range, across languages and cultures, and being relatively easy to administer and score.

Mathematics teacher survey. Equivalent English and French forms of this instrument were developed by the authors in consultation with school board personnel, to elicit key views of teachers about the newly developed mathematics document, the program, the institutional support received by the teachers, and the extent to which the teachers have used the new mathematics document in the school year 1981-82. The overall rationale for developing this survey was that a statistical relationship

may be found between degree of teachers' use of the new curriculum documents and mathematics achievement of their pupils.

Procedures

The mathematics teachers whose classes had been selected were asked to be the test administrators, for two main reasons: (a) this procedure enabled all instruments to be administered in all 12 classes within the space of approximately a week; and (b) the new mathematics achievement tests developed by the authors are intended for subsequent use by teachers, upon termination of this evaluation study. Prior to the administration of instruments, a training session was given by the authors to the teachers involved about the purpose of this evaluation study, the testing materials involved, how to administer the tests, and how to return all testing materials to the authors.

Pretesting. Form B, English version, of the objectives-based mathematics achievement test,was administered to the pupils in each of 8 English classes, and the same test form, French version, was administered to the pupils in each of 4 French immersion classes, in October 1981. October rather than September was selected for pretesting to enable the pupils to be properly settled in their new grade, and to enable the teachers involved to participate in the training session biven by the authors.

Posttesting. Both the mathematics test, Form A, English and French versions, and Cattell's test were given in May 1982, to the same pupils who had been pretested the previous October. The teacher survey was

mailed in May 1982, to all 12 participating teachers involved. They completed the survey on their own time and returned all materials to the authors.

In total, 223 pupils from 8 regular English program classes and 92 from 4 French immersion classes were pretested. Of these, 208 from 8 Erglish program classes and 81 from 4 French immersion classes were also posttested. All 12 participating teachers, 8 from English program classes and 4 from French immersion classes, completed the teacher survey.

Data Analysis

A two-way multivariate analysis of covariance was done to test the hypotheses. The independent variables were language of instruction (English versus French immersion), and teacher use of the mathematics curriculum document developed by the school board (higher versus lower reported use). To determine extent of teacher use of the document, the replies to seven items of the teacher survey were added, mean scores were computed, and higher versus lower groups were formed through a median split. Unfortunately, the mean scores of four teachers fell precisely at the median. Consequently, they and their pupils were excluded from the analysis.

The dependent variables were four sets of mathematics gain scores, obtained by subtracting pretest from posttest scores, for the arithmetic, geometry, graphing, and measurement strands. Each pupil's general aptitude was used as covariate to control statistically for possible differences among the groups contrasted.

## Results and Discussion

The gain score means and standard deviations in arithmetic, geometry, graphing, and measurement, for the regular English program and French immersion groups, are presented in Table 1.

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Insert Table 1 about here

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Table 1 shows the average progress of pupils from pretest to post-test on each of the four mathematics strands. The reader should note that the graphing strand involves only two test items.

The average standardized I.Q. score of the English program pupils was 111.3 ($n$ = 130), and that of the French immersion pupils was 118.8 ($n$ = 60). Therefore, this was used as a covariate in the contrasts to be shown in Table 2.

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Insert Table 2 about here

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Table 2 presents the results of a two-way multivariate and univariate analysis of covariance on the four mathematics gain scores. The univariate F-ratios given in Table 2 can be used to identify which of the four dependent variables contributed most to the overall significant difference between groups.

When the English and French immersion programs were contrasted, there was an overall significant difference ($F$ (4, 182) = 12.24, $p < .001$),

which indicates that the English program pupils made greater gains than their French immersion peers on each of four mathematics strands. This result seems to conflict with much available literature, which generally has found French immersion pupils to obtain comparable or higher mathematics scores in relation to those of English program peers (Barik & Swain, 1975; Bruck, Lambert, & Tucker, 1974; Swain, 1974; Genesee, Note 2). Two points should be noted. First, this result should be interpreted in the context that the pretest raw scores of the French immersion pupils were in fact higher than those of the English program pupils, but their rate of progress in mathematics was lower during the school year. Second, it must be borne in mind that previous studies have relied on standardized tests as measuring instruments. Such tests, because they must concentrate on the common core content taught across many school systems in different regions, are necessarily less specific than the specially constructed achievement test used in this study.

Table 2 also contrasts the gain scores of pupils whose teachers made relatively greater versus lesser use of the mathematics document. This contrast yielded an overall significant difference ($F$ (4, 182) = 12.62, $p < .001$) in the strands of arithmetic, geometry, and measurement. In all three cases, pupils whose teachers reported making relatively greater use of the curriculum document obtained substantially higher gain scores than pupils whose teachers reported relatively less use of the document.

As shown in Table 2, there was a significant interaction between the program and teacher variables ($F$ (4, 182) = 3.58, $p < .01$), for the arith-

metic strand only. With respect pupils whose teachers reported making greater use of the curriculum document, the arithmetic gain score mean of English program pupils ($\underline{M}$ = 4.53) was significantly higher than that of French immersion pupils ($\underline{M}$ = 3.16). On the other hand, considering pupils whose teachers reported making less use of the curriculum document, the arithmetic gain score mean of English program pupils ($\underline{M}$ = 1.00) was significantly lower than that of French immersion pupils ($\underline{M}$ = 2.02). The results confirm the hypotheses of the study in terms of arithmetic gain scores. The geometry, graphing, and measurement gain scores did not yield a statistically significant interaction.

Among the possible reasons for the above pattern of findings may be the fact that teachers, according to their teacher survey replies, believe that arithmetic should receive greater emphasis than the other strands at this grade level. It may well be that extensive use of the board's curriculum document, when reported in both programs, pertained primarily to the arithmetic strand, and that coverage of the other strands was less uniform across classes or programs.

In conclusion, the results of the present study revealed that English program pupils made greater progress in mathematics during grade three than did French immersion pupils, although the latter had higher initial average scores. This finding differs from much available literature. It was also found, regardless of program, that pupils whose

teachers reported relatively greater use of the school board's new curriculum document made more mathematics progress than did pupils whose teachers reported less use of the document. The combined effects of program and teacher variables indeed affected mathematics achievement of the grade three pupils, as predicted.

The present study provides educators and classroom teachers with more precise data on subject matter achievement of French immersion pupils, with specific reference to mathematics, and shows a statistical interaction between a program variable (language of instruction) and a teacher variable (use of new curriculum materials) as they relate to the achievement of the pupils.

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Table 1

Means and Standard Deviations of Pupils' Mathematics Gain Scores, by Program and Teacher Reported Use of Mathematics Document

| | | Mathematics Strand | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Arithmetic | | Geometry | | Graphing | | Measurement | |
| Group | n | M | SD | M | SD | M | SD | M | SD |
| English Prog. | | | | | | | | | |
| Higher Use | 77 | 4.53 | 2.71 | 2.74 | 2.17 | 0.60 | 0.67 | 4.00 | 3.07 |
| Lower Use | 53 | 1.00 | 3.04 | 1.83 | 2.05 | 0.34 | 0.99 | 2.43 | 2.68 |
| French Imm. Prog. | | | | | | | | | |
| Higher Use | 19 | 3.16 | 2.89 | 0.89 | 1.91 | 0.11 | 0.81 | 3.42 | 3.11 |
| Lower Use | 41 | 2.02 | 2.40 | 0.49 | 1.63 | 0.29 | 0.98 | 0.95 | 2.79 |

Table 2

Multivariate and Univariate Analysis of Covariance for Pupils' Mathematics Gain Scores, by Program and Teacher Reported Use of Mathematics Document

| Source of Variation | Multivariate $F$ (4, 182) | Univariate $F$ (1, 185) |
|---|---|---|
| Program (English vs French) | 12.24*** | |
| Arithmetic | | 5.76* |
| Geometry | | 37.72*** |
| Graphing | | 6.42** |
| Measurement | | 15.88*** |
| Teacher Use (Higher vs Lower) | 12.62*** | |
| Arithmetic | | 43.16*** |
| Geometry | | 5.08* |
| Graphing | | 0.50 |
| Measurement | | 15.69*** |
| Interaction | 3.58** | |
| Arithmetic | | 7.64** |
| Geometry | | 0.69 |
| Graphing | | 2.75 |
| Measurement | | 0.81 |

* $p < .05$
** $p < .01$
*** $p < .001$